THE CHEMISTRY OF FIRE AND SMOKE: THE COMPOSITION, AMOUNT, AND FATE OF SMOKE FROM RESIDUAL SMOLDERING COMBUSTION

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ABSTRACT

Smoke may present the most intractable barrier of all to implementing more enlightened fire management. The benefits of a prescribed fire program can only be realized if the public and regulatory agencies agree that the air quality impacts are acceptable. Currently, land managers can predict fuel consumption and smoke production from a planned burn using CONSUME and EPM and smoke transport with models such as NFSPUFF. Unfortunately, a potential, major source of smoke remains uncharacterized and is not included in these models. We are referring to residual smoldering combustion (RSC), which we define as combustion occurring after the convective-plume phase of a fire has ended; often lasting for many hours or days. It has been estimated that 50%, or more, of fuel consumption can occur by RSC under the driest conditions. Smoke generated by RSC can drift down-slope (especially at night) into smoke-sensitive areas. In combination with local inversion conditions, this may lead to air quality violations or complaints [e.g. “Inversion traps forest smoke, triggers air alert,” Missoulian, Oct. 24, 1998].

Currently, there are far more questions than answers about RSC. The actual fuel consumption, and the fuel consumption rate, by RSC have never been rigorously measured. We do not know if the gaseous composition of the smoke changes significantly during RSC, but we have preliminary evidence it does. This could impact ozone production in smoke plumes and ozone is the gaseous pollutant from burning most likely to exceed air quality regulations. The production of respirable particulate matter (PM2.5) per unit amount of fuel consumption during RSC is also unknown. This is important because PM2.5 is the fire emission of most concern from a health standpoint. The possible role of canopy recapture or delayed photochemical processing in modifying drift smoke is still uninvestigated. Finally, we wish to determine if there is a fuel moisture threshold, above which RSC is unlikely to be a problem. Quantification of this would be crucial for a trade-off analysis of the relative benefits of spring and fall burning.

We have begun to address these questions by developing a portable field apparatus to quantify the fluxes of gases and PM2.5 during RSC. We are using this to measure the temporal profile or “diedown rate” for RSC and determine if the integrated rate results agree with fuels inventory results. In addition, we are measuring smoke composition before and during RSC to screen for changes in the emission factors for many gases and PM2.5. We are also using the FSL combustion facility to burn well-characterized fuels at several different moisture contents and quantify the amount and the rate of smoke production. This will help determine the influence of fuel moisture content on RSC. Taken together, the results will assist in developing empirical models of RSC and useful “stand-alone” guidelines on predicting/avoiding RSC for land managers. These guidelines could also be readily integrated with CONSUME, EPM, fuels maps, and fire danger assessments.

Our studies include a powerful, new methodology to measure the amount and type of smoke produced by RSC that we have developed in a series of earlier experiments. The technique is open-path Fourier transform infrared

spectroscopy, which allows real-time remote sensing of dozens of chemical compounds in smoke. We have already made significant progress in clarifying the role of flaming and glowing combustion and pyrolysis in producing emissions. We have discovered numerous new, but important, smoke constituents and quantified the emissions from smoldering organic soils and duff. We also probed the effects of wind, fire retardant, fuel type, and fuel orientation on emissions and airborne experiments in North Carolina and Alaska dramatically confirmed the importance of our discoveries about smoke composition and ozone production in fire plumes.